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# UNIVERSITY PHYSICS

COMPLETE EDITION

by

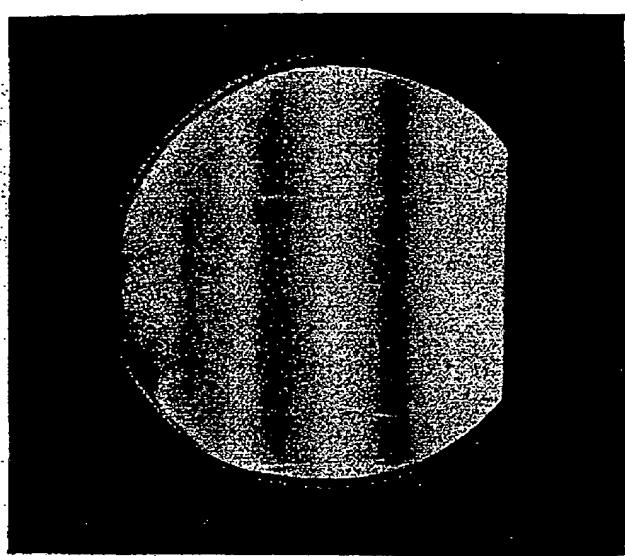
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and

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Interference colors in the light reflected  
from a thin soap film.

SECOND EDITION  
*with Supplementary Problems*

1955

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ble 28-1, the resistivity of copper is  $1.72 \times 10^{-8}$  ohm-m. Therefore,

$$E = \frac{1.72 \times 10^{-8} \text{ ohm}\cdot\text{m}}{10^{-4} \text{ m}^2} \times 200 \text{ amp}$$

$$= 0.0344 \text{ volt/m.}$$

**EXAMPLE 2.** What is the potential difference between two points on the above 10 m apart? Since the electric intensity or potential gradient is 0.0344 volt/m, the potential difference between two points 10 m apart is

$$V_a - V_b = 0.0344 \text{ volt/m} \times 100 \text{ m} = 3.44 \text{ volts.}$$

The more common method of solution would be to first compute the resistance of the wire from  $R = \rho L/A$  and then find the potential difference from  $V = IR$ . We have

$$R = \frac{1.72 \times 10^{-8} \text{ ohm}\cdot\text{m}}{10^{-4} \text{ m}^2} \times 100 \text{ m} = 0.0172 \text{ ohm.}$$

$$V_{ab} = 0.0172 \text{ ohm} \times 200 \text{ amp} = 3.44 \text{ volts,}$$

the same as the previous answer.

Richard M. Sharkansky

**3 Measurement of current, potential difference, and resistance.** Its are measured by instruments called *galvanometers* or *ammeters*. One common type makes use of the interaction between a current-carrying conductor and a magnetic field and is described in Chapter 32. For present purposes it is sufficient to know that such instruments measure the current at a point such as *a*, *b*, or *c* in Fig. 28-8(a), circuit must be opened and the ammeter inserted at that point so the current to be measured passes through the ammeter, as in Fig. 8(b). An ammeter is a low resistance instrument, representative being a few hundredths or thousandths of an ohm.

potential difference between two points of a circuit might be tested with an electroscope or electrometer. It is more convenient, to use some type of *voltmeter*, the construction of which is described more fully in Chapter 32. Most voltmeters, unlike electrosopes or electrometers, are current operated. The voltmeter terminals are tied to the points between which the potential difference is to be tested. Figure 28-8(b) shows a voltmeter *V* connected so as to measure the potential difference between the terminals of the cell. If the potential difference between the terminals of the cell. If the of its construction are disregarded, a voltmeter may be treated as a voltmeter which automatically indicates the potential difference between terminals. Typical resistances, for a 100-volt instrument, are from 100,000 ohms.

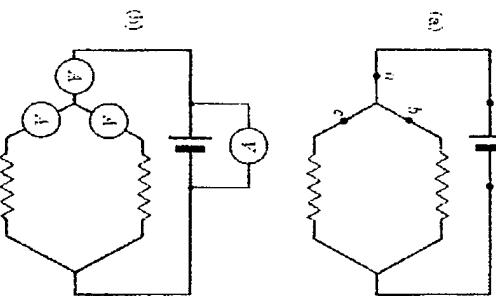
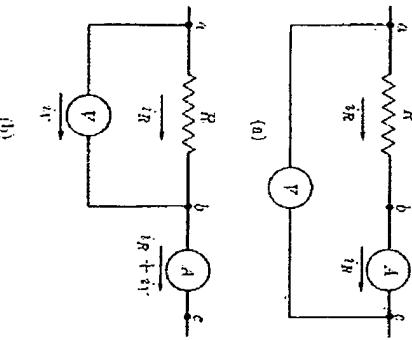


Fig. 28-8. Ammeter and voltmeter connections.

Fig. 28-9. Ammeter-voltmeter methods of measuring resistance.

The resistance of a conductor is the ratio of the potential difference between its terminals to the current in it. The most straightforward method of measuring resistance is therefore to measure these two quantities and divide one by the other. The ammeter-voltmeter method for so doing is illustrated in Fig. 28-9. In circuit (a) the ammeter measures the current  $i_R$  in the resistor, but the voltmeter reads  $V_{ab}$  and not the potential difference  $V_{ac}$  between the terminals of the resistor. In circuit (b) the voltmeter reads  $V_{ab}$  but the ammeter reads the sum of the currents in the resistor and in the voltmeter. Hence, whichever circuit is used, corrections must be made to the reading of one meter or the other, unless these corrections can be shown to be negligible.

**28-7 The Wheatstone bridge.** The Wheatstone bridge circuit, shown in Fig. 28-10, is widely used for the rapid and precise measurement of resistance. It was invented in 1843 by the English scientist, Charles Wheatstone. *M*, *N*, and *P* are adjustable resistors which have been previously calibrated, and *X* represents the unknown resistance. To use the bridge, switches *K*<sub>1</sub> and *K*<sub>2</sub> are closed and the resistance of *P* is adjusted until the galvanometer *G* shows no deflection. Points *b* and *c* must then be at the same potential or, in other words, the potential drop from *a* to *b* equals that from *a* to *c*. Also, the drop from *b* to *d* equals that from *c* to *d*. Since the galvanometer current is zero, the current in *M* equals



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FIGURE 28-71

28-71

## CURRENT AND RESISTANCE

500

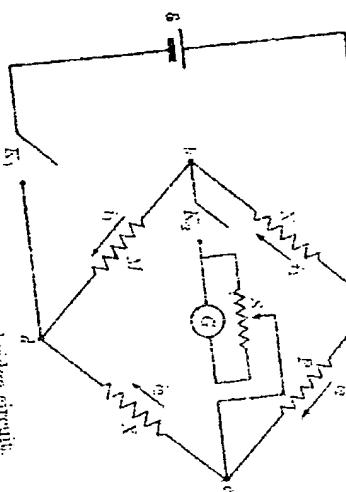


Fig. 28-10. Wheatstone bridge circuit.

that in  $N$ , say  $i_3$ , and the current in  $P$  equals that in  $X$ , say  $i_4$ . Then, since  $V_{ab} = V_{cd}$ , it follows that

$$i_1N = i_2P,$$

and since  $V_{bd} = V_{cd}$ ,

$$i_3M = i_4X.$$

When the second equation is divided by the first, we find

$$X = \frac{M}{N} P.$$

The ratio  $M/N$  is usually set at some integral power of 10, such as .01, 1, 100, etc., for simplicity in computation. Hence, if  $M$ ,  $N$ , and  $P$  are known,  $X$  can be computed.

During preliminary adjustments, when the bridge may be far from balance and  $V$  large, the galvanometer must be protected by the shunt  $S$ .

A resistor whose resistance is large compared with that of the galvanometer is permanently connected across the galvanometer terminals. When the sliding contact is at the left end of the resistor, none of the current in the path between  $b$  and  $c$  passes through the galvanometer. In a position such as that shown, part portion of the resistor, and this combination is shunted by that portion of the resistor, all of the current passes through only a fraction of the resistor, bypassed by the resistor. The sliding contact at the right of the resistor, at the left end of the contact, is shunted by that portion of the resistor except the small fraction is at the left end of the resistor and practically full galvanometer sensitivity is attained when the contact is at the right end.

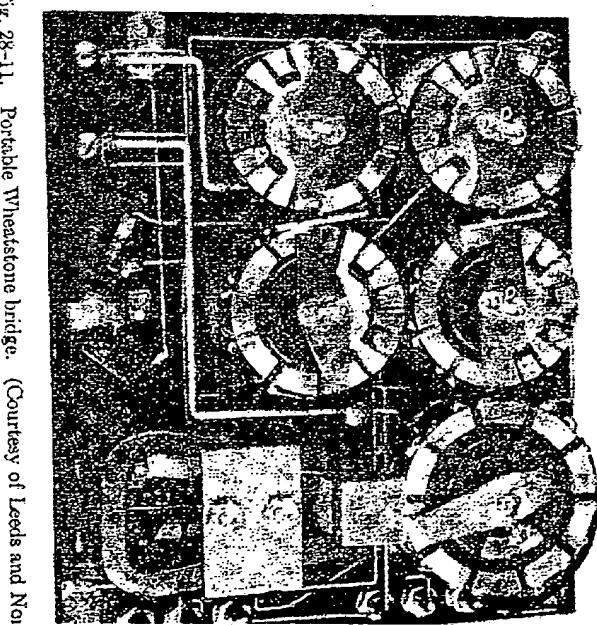


Fig. 28-11. Portable Wheatstone bridge. (Courtesy of Leeds and Northrup Co.)